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MULTIPLE FORMATION OF NUCLEON PAIRS AND OUTBURSTS OF SUPERNOVAE

(Mnozhestvennoye obrazovaniye nuklonnykh par i vspyshki sverkhnovykh)

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It is well known [1] that a body with a mass exceding the limit of stationary state upon exhaustion of nuclear sources of energy must come to a non-stationary state of the hydrostatically unlimited gravitational compression. However, not all the then possible physical processes have been examined in literature [2 – 4]. As it nears the gravitational radius, the kinetic (and consequently also the thermal) energy becomes comparable with the rest energy, which must lead to processes of multiple birth of particles. At the same time, and alongside with the already examined birth of hyperons and mesons [5 – 8], the multiple formation of nucleon pairs through π^c— mesons, heretofore neglected for one reason or another, must acquire a particlular significance. It follows from the general thermodynamic considerations, that the latter process is sharply facilitated in the presence of gravitational fields.

Let us start from the principle of detailed balance.

To the known annihilation process

$$N + \tilde{N} \longrightarrow m\pi^0 \qquad (1)$$

must correspond the reversible process of nucleon pair formation by neutral π-mesons:

$$m\pi^0 \rightleftarrows N + \tilde{N}. \qquad (2)$$

Let us find the equilibrium condition of that reaction. Inasmuch as π^0-mesons are their own antiparticles, their number is preserved in neither the arithmetic, nor the algebraic sense, and consequently their chemical potential is zero [1]. At the same time the equilibrium condition does not depend upon the number m of participating π^0-mesons, and has the form

$$\mu + \tilde{\mu} + 2m_0c^2\varphi = 0, \qquad (3)$$

where μ and $\tilde{\mu}$ respectively are the chemical potential of the nucleon and of the antinucleon in the absence of a field, φ is the gravitational potential within the spherical mass of radius R and uniform density ρ at a distance r from the center we have

$$\varphi = {}^2/_3\pi G\rho\,(r^2 - 3R^2). \qquad (4)$$

Condition (3) is based upon two admissions. Firstly, the formation of other particles besides π^0-mesons must not be compulsory at annihilation. Secondly, we admitted that the gravitational field acts equally on particles and antiparticles. The latter had already been the object of consideration a long time ago inasmuch as a deflection in the photon's gravitational field was observed at solar eclipses, the photon being its own antiparticle.

Let us see now, what approximation should the chemical potential be calculated to. The energy of nucleon degeneration is

$$E_n = m_n c^2 \sqrt{1 + \nu_n^2}, \qquad (5)$$

where the dimensionless density ν_n is linked with the number of particles in the volume unit $\underline{n}$ or with the usual density :

$$\nu_n = 3\pi^2 \lambda_n^3 n = 1{,}4 \cdot 10^{-16} \rho. \qquad (6)$$

Here $\lambda_n = \hbar / m_n c$ is the nucleon's Compton wavelength.

Thus, the relativistic degeneration of nucleons could only set in at densities exceeding by two orders the nuclear density. Limiting ourselves to densities not exceeding the nuclear density, we may consider that the degeneration energy is low in comparison with the rest energy. But the multiple formation processes of interest to us require thermal energies comparable with the rest energy. That is why we may consider the nucleons as being in a nondegenerate state. Under the conditions of interest to us the matter obviously finds itself already in a neutron state, and for densities below the nuclear density we may neglect the interaction. Equation (3) will then give for the formation equilibrium of pairs in an ideal neutron gas:

$$n\tilde{n} = 4 \left(\frac{m_n kT}{2\pi\hbar^2} \right)^3 e^{-2m_n (\varphi + c^2)/kT}. \qquad (7)$$

Since the gravitational potential φ is negative, the gravitational field facilitates the generation of pairs.

Let us now examine the course of the process of interest to us under hydrostatically unlimited compression of a sphere of uniform density, with a mass M, ecual to $\mathfrak{M}$ of solar masses. As is well known [2], hydrodynamics of the general theory of relativity, without accounting pressure forces, leads to the deduction, that the radius of the sphere tends to the gravitational radius

$$R_g = \frac{2GM}{c^2} \tag{8}$$

and the density tends correspondingly to the gravitational density

$$\rho_g = \frac{3}{32\pi}\,\frac{c^6}{G^3M^2} = \frac{2\cdot 10^{16}}{\mathfrak{M}^2}. \tag{9}$$

Let us introduce the compression parameter

$$\xi = \frac{R}{R_g} = \left(\frac{\rho_g}{\rho}\right)^{1/3} \tag{10}$$

and the thermalization coefficient

$$\beta = \frac{E_T}{E_g} = \frac{RkT}{m_n GM}. \tag{11}$$

So long as the concentration of nucleon pair is low, it will be expressed from (7) as

$$\frac{\widetilde{n}}{n} = \frac{9}{16}\,\pi\,\frac{\beta^3}{\nu^2\xi^3}\exp\left(\frac{A-4\xi}{\beta}\right), \tag{12}$$

where A is the number varying from 3 at the center of the sphere to 2 at its surface. Form (6) it is easy to express the dimensionless density ν by means of the gravitational density ρ_g and the parameter ξ:

$$\nu = 1{,}4\cdot 10^{-16}\,\frac{\rho_g}{\xi^3} = \frac{2{,}8}{\mathfrak{M}^2\xi^3}, \tag{13}$$

whence

$$\frac{\widetilde{n}}{n} = 0{,}22\,\beta^3\mathfrak{M}^4\xi^3\exp\left(\frac{A-4\xi}{\beta}\right). \tag{14}$$

As ξ nears the unity, the gravitational energy concept itself loses its sense. If $\tilde{n}/n$ is great, the mass increase on account of pair generation must be taken into account, which will quickly lead to values ξ, for which the formula deduced are inapplicable. But formula (14) allows the reaching of quite specific qualitative conclusions. To the examined sphere of uniform density corresponds the burned out nucleus of an heterogenous star. If its mass is of the order of the solar mass, the concentration of nucleon pairs is insignificant, according to (14). But for a mass of the order of 10 solar masses, formula (14) is quantitatively inapplicable, but the qualitative conclusion is evident: Practically all the matter must pass into nucleon pair state already in the region, where Newton's theory of attraction already is applicable.

We shall designate as e p i g r a v i t a t i o n a l p h e n o m e n a, all nucleon pair formations at gravitational compressions, as well as all sorts of phenomena in which nuclear and gravitational forces are manifest at the same time. The matter, consisting of nucleon pairs, stabilized by the gravitational field and a high temperature, really is a variety of charged particle plasma, which we shall designate as epigravitational plasma or e p i p l a s m a.

The formation of epiplasma in finite stages of star's compression prior to supernova outburst may have substantial astrophysical consequences. The difference in character of type I and II supernova explosions is getting a natural explanation [4, 5]. Type I supernovae, with a mass equalling 1.5 solar masses [4], have a gravitational density significantly higher than the nuclear density. Here the compression is stopped by repulsion forces between nucleons, long before reaching the gravitational radius. The dose of matter passing onto the state of nucleon pairs is small. At the same time, processes with lepton participation have a fundamental significance: the electron degeneration and formation of lepton pairs, leading to great gradients of electron pressure and of electric fields linked with them. The compression energy first transforms into electrostatic, then into magnetic and further into energy of superthermal particles emitting a nonthermal radiation in the magnetic fields [9, 10]. As to the type II supernovae with masses of the order of 10 solar masses, and higher, (see [4, 5]), they have to the contrary a gravitational density below the nuclear. Here the formation of nucleon pairs takes place in quantities many times exceeding the original quantity of matter even prior to reaching the nuclear density. At the same time, the ejected matter must also basically consist of epiplasma. The basic process at its expansion is the nucleon pair annihilation, at which only a small dose of energy passes to light. The annihilation process extends further in the interstellar gas region surrounding the place of outburst, and leads to hard emission from these regions.

The accounting of these epigravitational phenomena compels us to revise our concepts on the residues of supernova explosions. These must not be simple hign-density stars (white dwarfs or hypothetic neutral stars), but stars containing epiplasma within them. Their trapping interstellar gas must lead to a gradual substitution of antimatter by matter, with the ensuing annihilation of the antimatter liberated in the outer layers of the star. It is natural to assume that such annihilation processes must lead to instability, and have an unstationary course. At the same time there must form relativistic particles, emitting a non-thermal radiation in the magnetic fields. The diffusive character of the exchange process of antimatter into matter leads to the formation of a comparatively cold envelope around the dense epiplasmic nucleus. From that viewpoint, the residues of outbursts of type I-supernovae must consist of nonstationary red dwarfs (flashing stars) of the UV-Cetustype, and those of type II-supernovae — stars of type T-Taurus.

The latters' inclination to form associations is natural, as by the strength of brevity of the evolution path of stars with a great mass, the typeII-supernovae, flaring in contemporary times, are young stars with a plane component. Let us note that the epiplasma possesses many of those properties, which V. A. Ambtsum'yan [11] ascribed to the hypothetical " substellar matter ".

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**** THE END ****

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